Japanese Patent Application "Kokai" No. 9-23598

English translation of Excerpt from Detailed Disclosure

[0030]

[Embodiments] Embodiments of a magnet-embedded (flush) type motor relating to the present invention will be described next.

[0031] In the first embodiment, within a rotor, there is arranged an arc-shaped magnet along a surface contour of a cylindrical portion of the rotor, whereby a highly efficient motor with a reduced inductance Ld is obtained.

[0032] Fig. 1 is a section view of the magnet embedded motor according to the first embodiment of the invention. In Fig. 1, numeral 102 denotes a rotor core. Numeral 103 denotes the rotor cylindrical portion surface. Numeral 104 denotes a magnet insertion hole of the rotor core. Numeral 106 denotes a first magnetic. Numeral 108 denotes a second magnet. Numeral 110 denotes a shaft hole. Numeral 112 denotes a stator. Numeral 114 denotes a slot for insertion of stator winding (actual winding is not shown). Marks N, S represent magnet poles of only the stator 112 side.

[0033] The construction shown in Fig. 1 differs from the conventional construction only in the shape of the first magnet 106 and the rotor core 102 and the magnet insertion hole 104 associated therewith. In the following, the same portion as the conventional construction will be explained only briefly.

[0034] The rotor core 102 is formed by stacking silicon steel plates each being punched into a circular outer shape. Therefore, the rotor cylindrical portion surface 103 presents a cylindrical configuration. The rotor core 102 includes the magnet insertion holes 104 for allowing insertion of the first magnets 106 and the second magnets 108. And, in the magnet insertion holes, the first magnets 106 and the second magnets 108 are inserted, as illustrated in Fig. 1. In this, the first magnets 106 are arranged adjacent the rotor cylindrical portion surface. The magnets have a smaller magnetic flux transmissivity than the rotor core. Further, the shaft hole 110 is formed at the center of the silicon steel plates.

[0035] In the above, the shape of the first magnet 106 or of the rotor shown in Fig. 1 will be referred to herein as "reciprocal arcuate shape". Along the entire perimeter of these rotors, the stator 112 is present. To the slots 114 for insertion of the stator windings of the stator 112, there phases of windings, u, v, w, are wound. In operation, as an electric current is supplied to the windings, a rotating magnetic field is generated and the rotor is rotated in synchronism with this rotating magnetic field.

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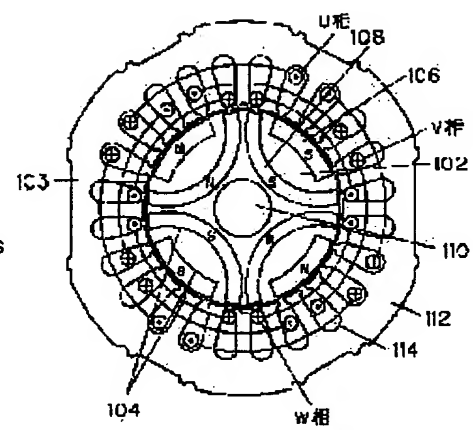
(54) MAGNET EMBEDDING TYPE MOTOR

(57)Abstract:
PROBLEM TO BE SOLVED: To provide a high efficiency motor having improved orthogonality between magnetic flux and current by forming one-pole magnet arranged at the inside of rotor with an arcuated first magnet and a second magnet of different shape and separated from the first magnet.
SOLUTION: A magnet inserting hole 104 is provided on a rotor iron core 102 and a first magnet 106 and a second magnet 108 are inserted thereto. Here, the first magnet 106 is arranged near the surface of the rotor cylinder 103. The magnetic flux permeability of the magnet is rather smaller than that of the rotor. The first magnet 106 or the rotor is formed in the normal or inverse arc. A stator 112 is provided in these rotors and to the entire circumference of the rotor. A 3-phase coil is wound to a slot 114 of the stator 112. Thereby, the generation of magnetic flux caused by the current can be reduced, the orthogonality between total magnetic flux and total current can be improved and a torque for the unit current is increased to realize a small sized motor assuring high efficiency and high output.



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CLAIMS

[Claim(s)]
[Claim 1] in the magnet flush-type motor which has two or more permanent magnets inside a rotor core, it is in part with the stator by which the coil was wound around the stator core, and a rotor core -- it is -- the magnet flush-type motor characterized by for the 1st magnet of the radii configuration where of the magnet for one pole which has arranged the all inside said rotator met the configuration of a rotator body front face, and said 1st magnet to consist of the 2nd magnet of a configuration which has dissociated and is different.
[Claim 2] The magnet flush type motor according to claim 1 characterized by being the radii configuration where the heights of the 2nd magnet turned to the revolving-shaft side.
[Claim 3] The magnet flush type motor according to claim 1 characterized by being the abbreviation rectangle configuration which the 2nd magnet has arranged to the radial direction.
[Claim 4] The stator by which the coil was wound around the stator core in the magnet flush-type motor which has two or more permanent magnets inside a rotor core, a rotor core, the 1st magnet of the abbreviation rectangle configuration which the magnet for one pole arranged inside said rotator has arranged [to / from / near the rotator body front face / near the rotator body front face], and said 1st magnet are the magnet flush-type motor characterized by to consist of the 2nd magnet of a configuration which has dissociated and is different.
[Claim 5] The magnet flush type motor according to claim 1 or 4 characterized by the production of said two side faces crossing at the inside based on revolving shafts since the magnet side face by the side of the periphery of the 1st magnet is reservation of a flux path.
[Claim 6] The magnet flush type motor according to claim 1 or 4 characterized by being cut by beveling etc. since the magnet corner by the side of the center of rotation of the 1st magnet is reservation of a flux path.
[Claim 7] In the magnet flush type motor which has two or more permanent magnets inside a rotor core It has the magnet which has arranged the all inside said rotator. it is in part with the stator by which the coil was wound around the stator core, and a rotor core -- it is -- The magnet flush type motor characterized by said rotor core for one pole preparing at least one of the large magnet insertion holes to an opening, notching, or a magnet towards the core of said pole near the edge of said pole respectively.
[Claim 8] The magnet flush type motor according to claim 7 characterized by said rotor core for one pole preparing at least one of the large magnet insertion holes in a part for the reverse flank of the hand of cut of said rotator to an opening, notching, or a magnet respectively.
[Claim 9] The magnet flush type motor according to claim 7 by which said rotor core for one pole is respectively characterized for an edge by preparing at least one of the large magnet insertion holes to an opening, notching, or a magnet so that it may become large by magnetic reluctance towards the core of to [near the edge of said pole for a reverse flank of the hand of cut of said rotator] said pole.
[Claim 10] The magnet flush type motor according to claim 7 by which the rotor core for one pole is respectively characterized by magnetic flux preparing 3% - about 45% of notching on the front face of a rotor core for said one pole in the body iron core front face for a reverse flank of the hand of cut of said rotator.
[Claim 11] The magnet flush type motor according to claim 7 by which a part for the reverse flank of the hand of cut of the rotator of the magnet insertion hole of the 2nd magnet established in the rotor core is characterized by the large thing to a magnet configuration.
[Claim 12] The magnet flush type motor according to claim 7 characterized by the 1st magnet moving to a hand of cut from a magnetic pole core.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application] This invention relates to the magnet flush type motor which uses reluctance torque and realizes small high power and a well head.
[0002]
[Description of the Prior Art] In recent years, the motor carried is wanted to attain a small high increase in power and efficient-ization similarly from the small high increase in power of the device carrying a motor, and a viewpoint of energy saving.
[0003] The small high increase in power of the motor using a permanent magnet and efficient-ization arrange a magnet on the interior of a rotor core, and can be realized by utilizing positively the reluctance torque component by the size of the magnetic reluctance (reluctance) of a rotor core while utilizing effectively the magnet torque which is a torque component with a magnet.
[0004] Hereafter, it explains, referring to drawing 15 about the conventional magnet flush type motor. For a rotor core and 553, as for the magnet insertion hole of a rotor core, the slot (an actual coil is omitted) in which in the 1st magnet and 558 an axial hole and 562 insert a stator in and, as for 564, the 2nd magnet and 560 insert [556] a stator winding, and 570, in drawing 15 , a rotator body front face and 554 are [552 / q shaft flux path and 580] d shaft flux paths. Moreover, d shaft and q shaft orientations are shown in drawing 15 . The magnetic polarity N and S show only a stator 112 side.
[0005] The actuation is explained while explaining a configuration to a detail about the conventional magnet flush type motor constituted as mentioned above.
[0006] A rotor core 552 carries out the laminating of the about 0.5mm silicon steel, and is made. The rotator body front face 553 expresses the appearance in which the rotator which has met the stator 562 carried out the shape of a cylindrical shape. And the magnet insertion hole 554 for a rotor core 552 to insert the 1st magnet 556 and the 2nd magnet 558 is made. And as shown in drawing 15 , the 1st magnet 556 and 2nd magnet 558 are inserted in the magnet insertion hole 554 (when there is especially no notice, suppose that the magnet is entered without a clearance in an insertion hole). Moreover, the axial hole 560 for letting a shaft pass is formed in the center of silicon steel. Here, the magnet is arranged two-layer at the reverse radii configuration, and the configuration of drawing 15 is considered as a two-layer reverse radii configuration. To these rotators, the gap of about 0.5mm is maintained at a rotator and the radial perimeter, it is fixed to them, and a stator 562 can rotate a rotator freely. By coiling the coil 564 (not shown) of a three phase circuit around a stator 562 here, and passing a current to the coil 562 of cage each phase, a revolving field is created and a rotator is rotated synchronizing with a revolving field.
[0007] In drawing 15 , d shaft takes the direction of magnetic flux with a magnet in the direction in which it and q shaft crossed at right angles. Then, the magnet torque Tm by magnet magnetic flux occurs by adding a current (q shaft current iq) to q shaft orientations (general actuation).
[0008] Here, a rotator shows q shaft flux path 570 and d shaft flux path 580 which are a path of the magnetic flux when passing q shaft and d shaft current to drawing 15 . q shaft flux path 570 mainly passes along between the 1st magnet 556 and the 2nd magnet 558. Namely, as for d shaft flux path 580, passage of magnetic flux can understand hindrance **** with a magnet with bad permeability rather than a rotor core 552 to passing only along a rotor core 552. Then, the reluctance torque Tr occurs according to an easy difference as the magnetic flux of q shaft of a rotor core 552, and d shaft. Easy is expressed using the inductances Lq and Ld which are motor constants as the magnetic flux of q shaft and d shaft. That is, in drawing 15 , it is Lq>Ld. A torque type is shown in (several 1).
[0009]
[Equation 1]

$T = \psi \cdot iq + (Ld - Lq) \cdot iq \cdot id$

[0010] Here, they are the flux linkage of psi:magnet, Ld, Lq:d, q shaft inductance, id, iq:d, and q shaft stator current. The magnet torque Tm and the 2nd term for which the 1st term used magnetic magnetic flux by (several 1) show the reluctance torque Tr. iq shows the torque current of the conventional surface magnet mold motor. Moreover, in order to generate the reluctance torque Tr by the reverse salient pole motor by the upper formula, id gives a negative value. The negative value of id is a direction which advances a current phase.
[0011] Here, id and iq will be set to (several 2) if the comprehensive current which carried out vector addition of id and the iq is set with I.
[0012]
[Equation 2]
$iq = I \cdot \cos\theta$
$id = I \cdot \sin\theta$

[0013] Here, theta shows the amount of current phase lead lag networks. It will be obtained if (several 2) is substituted for (several 1) (several 3).
[0014]
[Equation 3]
$$T = \psi I \cos\theta + (Ld - Lq) I \cos\theta \cdot I \sin\theta$$
$$= \psi I \cos\theta + 0.5 \cdot (Ld - Lq) I^2 \cdot \sin 2\theta$$

[0015] Here, the relation of the amount of current phase lead lag networks, and the magnet torque Tm, the reluctance torque Tr and the comprehensive torque (Tm+Tr) acquired from (several 3) is shown in drawing 16 .
[0016] In drawing 16 , when a current phase progresses 30 degrees, as for comprehensive torque, the maximum torque is obtained. Thus, by controlling a current phase to the optimal phase, the comprehensive torque more than Tm can be acquired and a small high increase in power can be attained.
[0017] Current phase thetat which obtains the maximum torque with the same current is obtained by (several 4) by carrying out the partial differential of (several 3) with the current phase theta, and setting with zero.
[0018]
[Equation 4]
$$\theta_1 = \frac{-\psi + \sqrt{\psi^2 + 8(Ld^2 - Lq^2) I^2}}{4(Ld - Lq) I}$$

[0019]
[Problem(s) to be Solved by the Invention] In the conventional magnet flush type motor, the magnet was arranged on the reverse radii configuration, and in order to acquire reluctance torque, it was thought that what is necessary was just to design Lq greatly. However, the orthogonality relation of magnetic flux and torque worsens as as Lq and (Ld-Lq) are enlarged. Therefore, it had the technical problem that the rate of the improvement in effectiveness worsened.
[0020] This thing is explained using drawing. The relation between magnetic flux and a current is shown in drawing 17 . phi, Lqiq, Ldid, and the comprehensive current I consist of id and iq for the comprehensive magnetic flux phi here. In drawing 17 , the comprehensive magnetic flux phi and the comprehensive current I serve as a phase of about 60 degrees. However, ** and I can carry out [torque]-izing of the magnetic flux most efficiently generated in the phase of 90 degrees. That is, torque is given by (several 5).
[0021]
[Equation 5]
$T = \Phi \cdot I \cdot \sin\theta$

[0022] That is, since torque cannot occur effectively to force current if the orthogonality relation of a current and magnetic flux worsens, it becomes a motor with bad drive effectiveness.
[0023] Furthermore, in order to obtain the maximum torque, when the current phase lead lag network was performed, as shown in the part of a phase lead lag network, and drawing 18 , Tm had the essential technical problem that it decreased.
[0024]
[Means for Solving the Problem] In order to solve the above-mentioned trouble, the magnet flush type motor of this invention is equipped with the 2nd magnet of a configuration which has separated a rotor core, the 1st magnet of the radii configuration where the magnet for one pole arranged inside a rotator met the configuration

of a rotator body front face, and the 1st magnet, and is different.
[0025] The magnet flush type motor of further others by this invention is equipped with the abbreviation rectangle configuration which the magnet for one pole of the 1st magnet has arranged [to / from / near the rotator body front face / near the rotator body front face].
[0026] The rotor core for one pole prepares respectively the magnet flush type motor of further others by this invention, and at least one which is a large magnet insertion hole to an opening, notching, or a magnet in a part for the reverse flank of the hand of cut of a rotator.
[0027]
[Function] When this invention arranges the 1st magnet with small magnetic-flux permeability by the above-mentioned configuration compared with a rotor core near the rotator body front face (forward radii configuration), the yield of the magnetic flux by id current decreases. That is, an inductance Ld decreases. By making an inductance Ld small, it is improved and the orthogonality of magnetic flux and a current serves as an efficient motor.
[0028] Moreover, by arranging the magnet of the abbreviation rectangle configuration arranged [to / from / near the rotator body front face / near the rotator body front face] inside a rotator, creation is easy, makes an inductance Ld small using the magnet of a low price, and serves as an efficient motor.
[0029] Furthermore, as for the magnetic flux of a magnet, the method opposite side of rotation of a rotator becomes strong by preparing an opening and notching in a part for the reverse flank of the hand of cut of the rotator of the rotor core which the magnetic flux for one pole generates respectively. This thing will decrease the magnetic flux in the case of the signs of the induced voltage by the current and magnet magnetic flux differing, and generating the negative torque Tm, if a current phase lead lag network is taken into consideration, it makes magnetic flux in case a current and magnetic flux generate the forward torque Tm of a same sign instead increased, stops the torque Tm decrement by the current phase lead lag network, enlarges comprehensive torque, and serves as an efficient motor.
[0030]
[Example] It explains referring to a drawing about the example of the magnet flush type motor of this invention below.
[0031] In the 1st example, by arranging the magnet of a radii configuration in accordance with the configuration of a rotator body front face inside a rotator, an inductance Ld is made small and it is made an efficient motor.
[0032] Drawing 1 is the sectional view of the magnet flush type motor which is equivalent to the 1st example of this invention. As for a rotor core and 103, in drawing 1 , 102 is [a rotator body front face and 104] the magnet insertion hole of a rotor core, and a slot (an actual coil is omitted) in which in the 1st magnet and 108 an axial hole and 112 insert a stator in and, as for 114, the 2nd magnet and 110 insert [106] a stator winding. N and S express only the polarity of the magnet by the side of a stator 112.
[0033] As for drawing 1 , in connection with it, a rotor core 102 and the magnet insertion hole 104 differ from the configuration of the 1st magnet 106 to the conventional example. Here, about a rotator configuration, the same place as the conventional example is described briefly.
[0034] An appearance carries out the laminating of the silicon steel pierced circularly, and the rotor core 102 is made. Therefore, the rotator body front face 103 shows the shape of a cylindrical shape. And the magnet insertion hole 104 for a rotor core 102 to insert the 1st magnet 106 and the 2nd magnet 108 is formed. And as shown in drawing 1 , the 1st magnet 106 and 2nd magnet 108 are inserted in the magnet insertion hole. Here, the 1st magnet 106 is arranged near the rotator body front face. Compared with a rotor core, magnetic-flux permeability of a magnet is small. Moreover, the axial hole 110 is formed in the center of silicon steel.
[0035] Here, the 1st magnet 106 of drawing 1 or the configuration of a rotator is considered as a forward reverse radii configuration. As opposed to these rotators, a stator 112 exists in a rotator and the perimeter. The coil of the three phase circuit of u, v, and w is wound around the slot 114 which inserts the stator winding of a stator 112. By passing a current to a coil, a revolving field is created and a rotator is rotated synchronizing with a revolving field.
[0036] The property of a motor of having the rotator of the configuration of drawing 1 is explained using drawing 2 and drawing 3 . Drawing 2 (a) is a line-of-magnetic-flux Fig. at the time of passing id current to a stator winding in the 1st example. Magnetic flux is proportional to an inductance L and a current. Then, if there is little magnetic flux, it means that an inductance is small. drawing 2 (b) shows the line-of-magnetic-flux Fig. at the time of it being alike in the 1st example and passing iq current. If it compares with drawing 2 (a), you can understand that magnetic flux has occurred [many directions in the case of passing iq] rather than it passes id. That is, as the conventional example described, it is Ld<Lq, and Tr is generated from (several 1).
[0037] Next, both the 1st conventional magnet and 2nd conventional magnet show [heights] the line-of-magnetic-flux Fig. at the time of giving id in the case of being the radii configuration (two-layer reverse radii

configuration) where the revolving-shaft side was turned to, and iq to drawing 3 (a) and (b). It is lost and it turns out [which the magnetic flux of drawing 2 (a) likes better than the magnetic flux of drawing 3 (a)] that the inductance Ld of the 1st example is smaller than the conventional example. Moreover, the magnitude of Lq is maintained by maintaining the clearance between the 1st magnet and the 2nd magnet. Therefore, the value of the difference (Ld-Lq) of an inductance is the same also as drawing 2 and drawing 3 , and reluctance torque can be utilized effectively similarly.

[0038] Here, the relation between inductance Ld change and the include angle between a current and magnetic flux is shown in drawing 4 . That is, an inductance Ld shows the result which an adult case (drawing 4 a) and adult Ld asked for the include angle beta of the phase thetat of the comprehensive current I and the comprehensive magnetic flux phi which calculated the case (drawing 4 b) (extreme example of Ld=0) where it was smallness to drawing 4 , keeping the difference (Ld-Lq) of an inductance constant from (several 4).

[0039] That is, by making an inductance Ld small, the orthogonality of a current and magnetic flux becomes good and the improvement in effectiveness of it is attained.

[0040] Furthermore, the structure of other rotators where the magnet of a forward radii configuration was formed like drawing 5 , drawing 6 , and drawing 7 is shown (since it is the same, a stator is omitted). Drawing 5 is an abbreviation rectangle configuration which the 2nd magnet 109 has arranged to the radial direction. A magnetic pole describes both N and S, when a stator 112 side cannot be judged. Drawing 6 is the configuration of having reduced the number of the 2nd magnet 111. Since the magnet side face by the side of the periphery of the 1st magnet 107 is reservation of q shaft flux path, drawing 7 is the configuration that the production of two side faces crosses at the inside based on revolving shafts. It cannot be overemphasized that an inductance Ld can be similarly made small in all, and efficient-ization can be attained.

[0041] It cannot be overemphasized that the stator side of the 1st magnet may be covered with the thin rotor core 104, a magnet front face may meet a stator as it is here in drawing 1 , drawing 5 , drawing 6 , drawing 7 , and below-mentioned drawing 14 , or whichever is sufficient.

[0042] Next, the magnet flush type motor of the 2nd example of this invention is explained. In the 2nd example, by arranging the magnet of the abbreviation rectangle configuration arranged [to / from / near the rotator body front face / near the rotator body front face] inside a rotator, creation is easy and uses an inductance Ld as a small efficient motor using the magnet of a low price.

[0043] Drawing 8 is the sectional view of the magnet flush type motor which is equivalent to the 2nd example of this invention. For a rotator body front face and 204, as for the 1st magnet and 108, in drawing 8 , the magnet insertion hole of a rotor core and 206 are [202 / a rotor core and 103 / the 2nd magnet and 110] axial holes. Drawing of the slot 114 which inserts a stator 112 and a stator winding was omitted.

[0044] As for the 2nd example, the rotor core 202 and the magnet insertion hole 204 differ from the configuration of the 1st magnet 206 with the formation of a form status change to the 1st example.

[0045] The rotator of the configuration of drawing 8 makes an inductance Ld small by the same view, and the improvement in effectiveness is as possible for it as the 1st example described. However, as shown in drawing 8 , compared with the 1st example, a thick rotor core is in the rotor core cylinder outside form side of the 1st magnet 206. Therefore, although an inductance Ld does not become small, it can make an inductance Ld sufficiently small to drawing 15 of the conventional example as the 1st example. Moreover, since the magnet corner by the side of the center of rotation is reservation of an inductance Lq flux path as shown in A of drawing 8 , the 1st magnet 206 is cut by beveling.

[0046] Since the cross section of the 1st magnet 206 is an abbreviation rectangle, it is easy to create the 2nd example, and the improvement in effectiveness is possible for it using a magnet with magnet creation expense there are few man days of post processing and cheap.

[0047] A ** R configuration etc. is sufficient as the configuration of the cut shown in A of drawing 8 . Next, the magnet flush type motor of the 3rd example of this invention is explained.

[0048] In the 3rd example, when the rotor core for one pole changes the direction of magnetic flux for notching in preparation for the reverse side of the hand of cut of a rotator, reduction of the magnet torque at the time of performing current phase-lead-lag-network control is suppressed, and an efficient motor is realized.

[0049] Drawing 9 is the sectional view of the magnet flush type motor which is equivalent to the 3rd example of this invention. For a rotor core and 304, as for a magnet and 110, in drawing 9 , the magnet insertion hole of a rotor core and 306 are [302 / an axial hole and 316] notching.

[0050] In this example, the magnet insertion hole 104 for inserting the 2nd magnet 108 of the 1st example shown in drawing 1 and the 2nd magnet 108 was lost, and notching 316 is added. Drawing of the slot 114 which inserts a stator 112 and a stator winding was omitted.

[0051] Notching 316 has penetrated the rotor core 302 to shaft orientations. The effectiveness is explained using drawing 10 - drawing 14 .

[0052] An induced voltage wave and torque according to the current for a plane 1 and magnet magnetic flux respectively when there is no current progress in drawing 10 are shown. The axis of ordinate of drawing 10 - drawing 12 gives a suitable numeric value, and shows the standard of magnitude. In order to make torque legible, it shows the value calculated with torque =2x current x induced voltage. Since there is no current phase lead lag network, the sign of a current and induced voltage is the same, and there is no place where the torque for a plane 1 shows negative. When Tm for a plane 1 of drawing 10 is generated, in drawing 23 , a current phase lead lag network corresponds to 0 times, and Tm is max. Here, the torque which a motor generates will be acquired, if it adds three torque from which the phase shifted by a unit of 120 degrees in passing the current of a three phase circuit to a stator.
[0053] As for drawing 11 , at least that for a plane 1 in the conventional example shows the induced voltage wave and torque by the phase leading current and magnet magnetic flux. In drawing 11 , the current phase is advanced 30 degrees. If a current phase is advanced, as shown in drawing 11 , negative torque will occur and only the part to which the phase of an induced voltage wave and a current shifted, and the current phase progressed will cause [of magnet torque] reduction. The decrement of Tm in the case of having generated the torque of drawing 11 is shown in drawing 23 .
[0054] Magnetic magnetic flux is decreased in the part which generates torque negative by forming notching 316 like drawing 9 to the former. Change of the direction of the magnet magnetic flux by the current impression location and notching of the 180-degree section whose current in the case of adding the sinusoidal current of phase progress to drawing 13 about 30 degrees is a same sign is shown. Moreover, as for drawing 12 , at least that for a plane 1 in the 3rd example shows the induced voltage wave and torque by the phase leading current and magnet magnetic flux. (I think that drawing 12 is enough for an induced voltage wave to understand the work although it becomes the wave which did not become such strictly but was distorted.) The magnetic flux which generates negative torque as shown in drawing 12 and drawing 13 is decreased. Moreover, the magnetic flux of the part goes to the place which generates forward torque, increases the magnetic flux which contributes to generating forward torque, and increases forward torque.
[0055] A current phase and torque are shown in drawing 14 . That is, negative torque is decreased, forward torque increases, and since the decrement of Tm shown in drawing 23 decreases, comprehensive torque will increase (reluctance torque becomes small to the former strictly.).
[0056] Thus, even if it advances a current phase, Tm will seldom decrease but the torque yield to the same current will increase, and it becomes realizable [a small well head].
[0057] Moreover, the rotator at the time of decreasing the magnetic pole of six poles at the time of establishing an opening 318 in the rotator body front face by the side of the reverse of the hand of cut of one pole each at drawing 15 and a magnet 306 is shown. The comprehensive torque result by the simulation at the time of changing the case of an opening 318 and an opening 318 into drawing 16 in an iron core (there being no opening) is shown. It is in ** that comprehensive torque increases by the opening 318, and it cannot be overemphasized that the same effectiveness is acquired.
[0058] Next, other rotator structures in the 3rd example of this invention are shown in drawing 17 -18. Drawing which enlarged notching to about 40% on the front face of a rotor core is shown in drawing 17 . Moreover, since drawing 18 makes [many] the amount of notching like the edge of a magnetic pole, the edge is large [an air gap (magnetic reluctance)], and induced voltage becomes large towards a magnetic pole core. The percentage to the rotor core front face for one pole of notching incidentally shown in drawing 9 is about 9%. That is, I think that it is usually good at 3% - about 15%. However, when often driving by about 40 to 60 large phase lead lag network, notching is considered to be [about 45%] effective.
[0059] Furthermore, drawing 18 is drawing at the time of adopting the 1st example and 3rd example as **. Drawing 17 enlarged the configuration of the magnet insertion hole 305 by the side of the reverse of the hand of cut of one pole each to the magnet configuration. In order to secure the flux path of q shaft between magnets in the two-layer magnet of the 1st magnet 106 and the 2nd magnet 108 furthermore, the 1st magnet 107 is making it move to a hand of cut from a magnetic pole core. The effectiveness which the 1st example and the 3rd example multiplied is acquired by this thing.
[0060] Moreover, drawing 18 is the case where the both ends of the rotor core equivalent to one pole are equipped with notching 317. In drawing 18 , from the case where induced voltage with a magnet shows drawing 12 , further, a center section (a current phase is near 90 degrees) becomes large, and an edge (a current phase is near 0 - 30 degrees) becomes small by notching. This structure is effective especially when [that a drive current phase lead lag network is small (less than 30 degrees)] there is little use of reluctance torque. Since the gap of the phase of induced voltage and a current phase with a magnet is small, by enlarging induced voltage in the large part of a current, the torque yield to the same current will increase similarly, and it becomes realizable [a small well head].

[0061] The 3rd example is effective, when the hand of cut inclines toward the clockwise rotation or the counterclockwise rotation, or when effectiveness is thought as important only in one hand of cut.
[0062] Although the sinusoidal drive was described here, it cannot be overemphasized that the same effectiveness is acquired also in a square wave drive. Moreover, the same effectiveness is acquired even if the source resultant pulse number of a stator changes.
[0063] Since the one where magnet thickness is thinner is not interrupted for an opening etc. with a magnet using a magnet with high flux density, the effectiveness of notching for [of a magnet] making a magnetic-flux change shows up better, rather than magnet thickness is still thicker.
[0064] It cannot be overemphasized that effectiveness has [in / further / one layer and not only two-layer but / a multilayer] a magnet to one pole.
[0065]
[Effect of the Invention] This invention makes the yield of the magnetic flux by id current decrease by having the 2nd magnet of a configuration which has separated the 1st magnet of the radii configuration where the magnet for one pole arranged inside a rotator met the configuration of a rotator body front face, and the 1st magnet, and is different. Therefore, it is improved, the torque over a unit current increases, and the orthogonality of comprehensive magnetic flux and a comprehensive current can realize the motor of efficient-izing and small high power.

[Translation done.]

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] The sectional view of the magnet flush type motor which is equivalent to the 1st example of this invention
[Drawing 2] The line-of-magnetic-flux Fig. at the time of passing a current to a stator winding in the 1st example of this invention
[Drawing 3] The line-of-magnetic-flux Fig. at the time of passing a current to a stator winding in the two-layer reverse radii configuration of the conventional example
[Drawing 4] Drawing showing the relation between Ld and the include angle between a current and magnetic flux
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[Drawing 16] Drawing showing other rotator structure in the 3rd example of this invention, and its simulation result
[Drawing 17] Drawing showing other rotator structures in the 3rd example of this invention
[Drawing 18] Drawing showing other rotator structures in the 3rd example of this invention
[Drawing 19] Drawing showing other rotator structures in the 3rd example of this invention
[Drawing 20] The sectional view of the magnet flush type motor in the conventional example
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[Drawing 22] Drawing showing the relation between a comprehensive current and comprehensive magnetic flux
[Drawing 23] Drawing showing the relation between the maximum torque current phase in the conventional example, and the decrement of Tm
[Description of Notations]
106 1st Magnet
108 2nd Magnet
104 Magnet Insertion Hole 316 Notching
318 Opening

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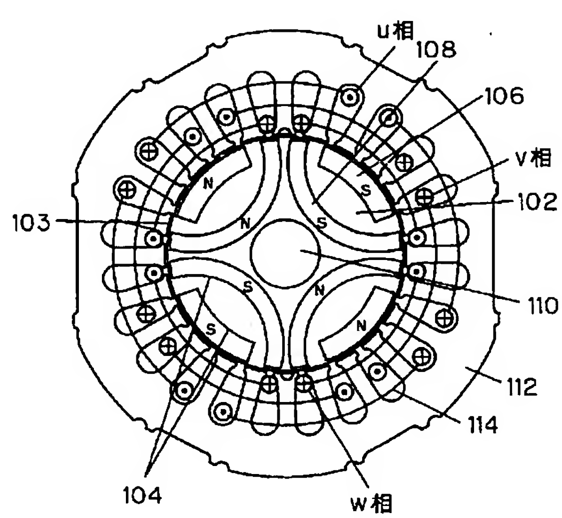
(54)【発明の名称】磁石埋込形モータ

(57)【要約】
【目的】　本発明は回転子鉄心内部に磁石を配しリラクタンストルクを積極的に活用することにより小型高出力化、高効率化を実現する磁石埋込形モータに関するものであり、リラクタンストルクを利用する場合に生ずる磁束と電流との関係の改善しモータを高効率化する事を目的とする。
【構成】　第1の磁石106を回転子円筒部表面の形状に沿って円弧形状に配置した、あるいは略長方形形状の磁石を回転子円筒部表面近傍から回転子円筒部表面近傍まで配置した事でid電流による磁束の発生量を減少させる。そのため総合磁束と総合電流との直交性は改善され、単位電流に対するトルクが増加して高効率モータが実現できる。

102　回転子鉄心
104　磁石挿入穴
106　第1の磁石
108　第2の磁石
112　固定子



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【特許請求の範囲】

【請求項１】回転子鉄心の内部に複数個の永久磁石を有する磁石埋込形モータにおいて、固定子鉄心に巻線が巻回された固定子と、回転子鉄心と、一部あるいはその全てを前記回転子の内部に配置した１極分の磁石が回転子円筒部表面の形状に沿った円弧形状の第１の磁石と、前記第１の磁石とは分離しており異なる形状の第２の磁石とからなることを特徴とする磁石埋込形モータ。

【請求項２】第２の磁石の凸部が回転軸側に向いた円弧形状であることを特徴とする請求項１記載の磁石埋込形モータ。

【請求項３】第２の磁石がラジアル方向に配置した略長方形形状であることを特徴とする請求項１記載の磁石埋込形モータ。

【請求項４】回転子鉄心の内部に複数個の永久磁石を有する磁石埋込形モータにおいて、固定子鉄心に巻線が巻回された固定子と、回転子鉄心と、前記回転子の内部に配置した１極分の磁石が回転子円筒部表面近傍から回転子円筒部表面近傍まで配置した略長方形形状の第１の磁石と、前記第１の磁石とは分離しており異なる形状の第２の磁石とからなることを特徴とする磁石埋込形モータ。

【請求項５】第１の磁石の円周側の磁石側面が磁束通路の確保のため前記２つの側面の延長線が回転軸中心の内側で交わることを特徴とする請求項１または４記載の磁石埋込形モータ。

【請求項６】第１の磁石の回転中心側の磁石角部が磁束通路の確保のため面取り等によりカットされていることを特徴とする請求項１または４記載の磁石埋込形モータ。

【請求項７】回転子鉄心の内部に複数個の永久磁石を有する磁石埋込形モータにおいて、固定子鉄心に巻線が巻回された固定子と、回転子鉄心と、一部あるいはその全てを前記回転子の内部に配置した磁石とを備え、各々１極分の前記回転子鉄心が前記極の端部近傍から前記極の中心に向けて空隙や切り欠きや磁石に対して大きい磁石挿入穴の少なくとも１つを設けることを特徴とする磁石埋込形モータ。

【請求項８】各々１極分の前記回転子鉄心が前記回転子の回転方向の逆側部分に空隙や切り欠きや磁石に対して大きい磁石挿入穴の少なくとも１つを設けることを特徴とする請求項７記載の磁石埋込形モータ。

【請求項９】各々１極分の前記回転子鉄心が前記回転子の回転方向の逆側部分の前記極の端部近傍から前記極の中心に向けて端部ほど磁気抵抗が大きくなるよう空隙や切り欠きや磁石に対して大きい磁石挿入穴の少なくとも１つを設けることを特徴とする請求項７記載の磁石埋込形モータ。

【請求項１０】各々１極分の回転子鉄心が磁束が前記回転子の回転方向の逆側部分の円筒部鉄心表面に前記１極分の回転子鉄心表面の３％～４５％程度の切り欠きを設けることを特徴とする請求項７記載の磁石埋込形モータ。

【請求項１１】回転子鉄心に設けた第２の磁石の磁石挿入穴の回転子の回転方向の逆側部分が磁石形状に対して大きいことを特徴とする請求項７記載の磁石埋込形モータ。

【請求項１２】第１の磁石が磁極中心から回転方向へ移動したことを特徴とする請求項７記載の磁石埋込形モータ。

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【発明の詳細な説明】

【０００１】

【産業上の利用分野】本発明はリラクタンストルクを利用し小型高出力、高効率を実現する磁石埋込形モータに関するものである。

【０００２】

【従来の技術】近年、モータを搭載する機器の小型高出力化、また省エネルギーの観点から、搭載されるモータも同様に小型高出力化、高効率化を図る事が望まれている。

【０００３】永久磁石を用いたモータの小型高出力化、高効率化は、磁石によるトルク成分であるマグネットトルクを有効に活用すると共に、回転子鉄心内部に磁石を配し、回転子鉄心の磁気抵抗（リラクタンス）の大小によるリラクタンストルク成分を積極的に活用することにより実現できる。

【０００４】以下、従来の磁石埋込形モータについて図１５を参照しながら説明する。図１５において、５５２は回転子鉄心、５５３は回転子円筒部表面、５５４は回転子鉄心の磁石挿入穴、５５６は第１の磁石、５５８は第２の磁石、５６０は軸穴、５６２は固定子、５６４は固定子巻線を挿入するスロット（実際の巻線は省略）、５７０はｑ軸磁束通路、５８０はｄ軸磁束通路である。またｄ軸とｑ軸方向を図１５に示す。磁石の極性Ｎ、Ｓは固定子１１２側のみを示す。

【０００５】以上のように構成された従来の磁石埋込形モータについて、詳細に構成を説明すると共にその動作について説明する。

【０００６】回転子鉄心５５２は０．５ｍｍ程度の珪素鋼板を積層して作られている。回転子円筒部表面５５３は固定子５６２に対面している回転子の円筒形状した外形を表す。そして回転子鉄心５５２は第１の磁石５５６、第２の磁石５５８を挿入するための磁石挿入穴５５４があけられている。そして磁石挿入穴５５４には図１５に示すように第１の磁石５５６と第２の磁石５５８が挿入されている（特にことわりがない場合は挿入穴に磁石は隙間なく入っている事とする）。また珪素鋼板の中央に軸を通すための軸穴５６０が設けられている。ここで、図１５の形状は逆円弧形状に磁石が２層に配置されており、２層逆円弧形状という事とする。これらの回転

子に対し、固定子５６２は回転子と半径方向全周に０．５ｍｍ程度のギャップを保ち固定されており、回転子は回転自在である。ここで固定子５６２には３相の巻線５６４（図示せず）が巻かれおり各相の巻線５６２に電流を流す事により回転界磁を作成し、回転子は回転界磁に同期して回転する。

【０００７】図１５において、ｄ軸は磁石による磁束の方向を、ｑ軸はそれと直交した方向にとる。そこでｑ軸方向に電流（ｑ軸電流ｉｑ）を加えることにより磁石磁束によるマグネットトルクTmが発生する（一般的な動作）。

【０００８】ここで、図１５に回転子ではｑ軸、ｄ軸電流を流した時の磁束の通路であるｑ軸磁束通路５７０とｄ軸磁束通路５８０を示す。ｑ軸磁束通路５７０は第１の磁石５５６と第２の磁石５５８の間を主として通る。即ち回転子鉄心５５２のみを通るのに対し、ｄ軸磁束通路５８０は回転子鉄心５５２よりも透磁率の悪い磁石により磁束の通過が妨げらる事が理解できる。そこで、回転子鉄心５５２のｑ軸とｄ軸の磁束の通り易さの差によってリラクタンストルクTrが発生する。ｑ軸、ｄ軸の磁束の通り易さはモータ定数であるインダクタンスＬｑ、Ｌdを用いて表される。即ち図１５ではLq＞Ｌdとなっている。（数１）にトルク式を示す。

【０００９】

【数１】

$$T=\psi\cdot iq+(Ld-Lq)\cdot iq\cdot id$$

【００１０】ここで、ϕ：磁石の鎖交磁束、Ld, Lq：ｄ，ｑ軸インダクタンス、ｉd, ｉｑ：ｄ，ｑ軸固定子電流である。（数１）で第１項は磁石の磁束を利用したマグネットトルクTm、第２項はリラクタンストルクTrを示す。ｉqは従来の表面磁石型モータのトルク電流を示す。また、上式で逆突極モータでリラクタンストルクＴrを発生させるためｉdは負の値を与える。ｉdの負の値は電流位相を進める方向である。

【００１１】ここで、ｉd, ｉqをベクトル加算した総合電流をＩとおくと、ｉd, ｉqは（数２）となる。

【００１２】

【数２】

$$iq=I\cdot\cos\theta$$
$$id=I\cdot\sin\theta$$

【００１３】ここで、θは電流位相進み量を示す。（数２）を（数１）に代入すると（数３）が得られる。

【００１４】

【数３】

$$\begin{aligned}T&=\psi I\cos\theta+(Ld-Lq)I\cos\theta\cdot I\sin\theta\\&=\psi I\cos\theta+0.5\cdot(Ld-Lq)I^2\cdot\sin2\theta\end{aligned}$$

【００１５】ここで、（数３）より得られる電流位相進み量とマグネットトルクTm、リラクタンストルクTr、総合トルク（Tm＋Tr）との関係を図１６に示す。

【００１６】図１６では電流位相が３０度進んだ場合に総合トルクは最大トルクが得られている。このように電流位相を最適な位相に制御する事により、Tm以上の総合トルクを得る事ができ小型高出力化を図れる事となる。

【００１７】同一電流で最大トルクを得る電流位相θtは（数３）を電流位相θで偏微分し零とおく事により（数４）で得られる。

【００１８】

【数４】

$$\theta_1=\frac{-\psi+\sqrt{\psi^2+8(Ld^2-Lq^2)I^2}}{4(Ld-Lq)I}$$

【００１９】

【発明が解決しようとする課題】従来の磁石埋込形モータにおいては、逆円弧形状に磁石を配し、リラクタンストルクを得るためにLqを大きく設計すれば良いと考えられていた。しかし、Lq、（Ld－Lq）を大きくするに従ってと磁束とトルクとの直交関係が悪くなる。そのため効率向上率が悪くなるという課題を有していた。

【００２０】この事を図を用いて説明する。磁束と電流との関係を図１７に示す。ここで総合磁束Φはϕ、Lqｉq、Ldｉd、総合電流Ｉはｉd、ｉqから構成される。図１７において総合磁束Φと総合電流Ｉとは６０度程度の位相となっている。しかしΦとＩは９０度の位相で最も効率よく発生した磁束をトルク化できる事となる。即ちトルクは（数５）で与えられる。

【００２１】

【数５】

$$T=\Phi\cdot I\cdot\sin\theta$$

【００２２】即ち、電流と磁束との直交関係が悪くなると印加電流に対しトルクが有効に発生できないため駆動効率の悪いモータとなる。

【００２３】さらに、最大トルクを得るため電流位相進みを行うと位相進みの分、図１８に示すようにTmは減少するという本質的な課題があった。

【００２４】

【課題を解決するための手段】上記問題点を解決するために本発明の磁石埋込形モータは回転子鉄心と、回転子の内部に配置した１極分の磁石が回転子円筒部表面の形状に沿った円弧形状の第１の磁石と、第１の磁石とは分離しており異なる形状の第２の磁石とを備えたものである。

【００２５】本発明による更に他の磁石埋込形モータは、第１の磁石の１極分の磁石が回転子円筒部表面近傍から回転子円筒部表面近傍まで配置した略長方形形状を備えたものである。

【００２６】本発明による更に他の磁石埋込形モータ、各々１極分の回転子鉄心が回転子の回転方向の逆側部分に空隙や切り欠きや磁石に対して大きい磁石挿入穴の少なくとも１つを設けたものである。

【0027】
【作用】本発明は上記した構成によって、回転子円筒部表面近傍に回転子鉄心に比べ磁束透磁率が小さい第1の磁石を配置（正円弧形状）する事により、id電流による磁束の発生量は減少する。即ちインダクタンスLdは減少する。インダクタンスLdを小さくする事により磁束と電流との直交性は改善され高効率モータとなる。

【0028】また、回転子の内部に回転子円筒部表面近傍から回転子円筒部表面近傍まで配置した略長方形形状の磁石を配置する事により、作成が簡単で低価格の磁石を用いてインダクタンスLdを小さくし高効率なモータとなる。

【0029】さらに、各々１極分の磁束が発生する回転子鉄心の回転子の回転方向の逆側部分に空隙や切り欠きを設ける事により、マグネットの磁束は回転子の回転方向側が強くなる。この事は電流位相進みを考慮すると電流と磁石磁束による誘起電圧の符号が異なり負のトルクTmを発生させる場合の磁束を減少させ、かわりに電流と磁束が同符号の正のトルクTmを発生させる場合の磁束を増加させる事となり、電流位相進みによるトルクTm減少分を抑え総合トルクを大きくさせ高効率なモータとなる。

【0030】
【実施例】以下本発明の磁石埋込形モータの実施例について図面を参照しながら説明する。

【0031】第1の実施例では、回転子の内部に回転子円筒部表面の形状に沿って円弧形状の磁石を配置する事によりインダクタンスLdを小さくし高効率なモータにするものである。

【0032】図1は本発明の第1の実施例にあたる磁石埋込形モータの断面図である。図1において、102は回転子鉄心、103は回転子円筒部表面、104は回転子鉄心の磁石挿入穴、106は第1の磁石、108は第2の磁石、110は軸穴、112は固定子、114は固定子巻線を挿入するスロット（実際の巻線は省略）である。N、Sは固定子112側の磁石の極性のみを表す。

【0033】図1は従来例に対し、第1の磁石106の形状と、それに伴って回転子鉄心102と磁石挿入穴104が異なる。ここで、回転子構成に関しては従来例と同じ所は簡単に述べる。

【0034】回転子鉄心102は外形が円形に打ち抜かれた珪素鋼板を積層して作られている。そのため、回転子円筒部表面103は円筒形状を示す。そして回転子鉄心102は第1の磁石106、第2の磁石108を挿入するための磁石挿入穴104が設けられている。そして磁石挿入穴には図1に示すように第1の磁石106と第2の磁石108が挿入されている。ここで、第1の磁石106は回転子円筒部表面近傍に配置される。磁石は回転子鉄心に比べ磁束透磁率が小さい。また珪素鋼板の中央に軸穴110が設けられている。

【0035】ここで、図1の第1の磁石106あるいは回転子の形状を正逆円弧形状という事とする。これらの回転子に対し、また回転子と全周に固定子112が存在する。固定子112の固定子巻線を挿入するスロット114にはu、v、wの3相の巻線が巻回されている。巻線に電流を流す事により回転界磁を作成し、回転子は回転界磁に同期して回転する。

【0036】図1の構成の回転子を有するモータの特性を図2、図3を用いて説明する。図2（a）は第1の実施例において固定子巻線にid電流を流した場合の磁束線図である。磁束はインダクタンスLと電流に比例する。そこで、磁束が少ないとインダクタンスが小さい事を意味する。図2（b）は第1の実施例においてにiq電流を流した場合の磁束線図を示す。図2（a）と比較すればidを流すよりもiqを流す場合の方が磁束が多く発生している事が理解できる。即ち、従来例で述べたようにLd＜Lqであり、（数1）よりTrを発生する。

【0037】次に従来の第1の磁石と第2の磁石が両方とも凸部が回転軸側に向いた円弧形状（2層逆円弧形状）である場合のid、iqを与えた場合の磁束線図を図3（a）、（b）に示す。図2（a）の磁束が図3（a）の磁束よりすくなくなり、第1の実施例のインダクタンスLdが従来例より小さくなっている事が分かる。また第1の磁石と第2の磁石との隙間を保つ事によりLqの大きさは保たれる。そのため図2、図3ともインダクタンスの差（Ld－Lq）の値は同じであり、リラクタンストルクは同様に有効に活用できる。

【0038】ここで、図4にインダクタンスLd変化と電流,磁束間の角度との関係を示す。即ち、（数4）よりインダクタンスの差（Ld－Lq）を一定に保ったままインダクタンスLdが大の場合（図4a）とLdが小の場合（図4b）（Ld＝0の極端な例）を計算した総合電流Iの位相θtと総合磁束Φとの角度βを求めた結果を図4に示す。

【0039】即ちインダクタンスLdを小さくする事により電流と磁束との直交性は良くなり効率向上が可能となる。

【0040】さらに、図5、図6、図7に同様に正円弧形状の磁石を設けた他の回転子の構造を示す（固定子は同様であるため省略）。図5は第2の磁石109がラジアル方向に配置した略長方形形状である。磁極は固定子112側を判断できない場合はN、Sの両方を記す。図6は第2の磁石111の個数を減らした構成である。図7は第1の磁石107の円周側の磁石側面がq軸磁束通路の確保のため2つの側面の延長線が回転軸中心の内側で交わる構成である。全てにおいて同様にインダクタンスLdを小さくでき高効率化を図れる事は言うまでもない。

【0041】ここで、図1、図5、図6、図7及び後述の図14において、第1の磁石の固定子側は薄い回転子

鉄心１０４に覆われていても、磁石表面がそのまま固定子に対面してもどちらでも良い事は言うまでもない。

【００４２】次に本発明の第２の実施例の磁石埋込形モータについて説明する。第２の実施例では、回転子の内部に回転子円筒部表面近傍から回転子円筒部表面近傍まで配置した略長方形形状の磁石を配置する事により、作成が簡単で低価格の磁石を用いてインダクタンスLdを小さく高効率なモータにするものである。

【００４３】図８は本発明の第２の実施例にあたる磁石埋込形モータの断面図である。図８において、２０２は回転子鉄心、１０３は回転子円筒部表面、２０４は回転子鉄心の磁石挿入穴、２０６は第１の磁石、１０８は第２の磁石、１１０は軸穴である。固定子１１２、固定子巻線を挿入するスロット１１４の図は省略した。

【００４４】第１の実施例に対し第２の実施例は第１の磁石２０６の形状と、形状変化に伴って回転子鉄心２０２、磁石挿入穴２０４が異なっている。

【００４５】図８の構成の回転子は第１の実施例で述べたのと同様の考え方によりインダクタンスLdを小さくし効率向上が可能である。しかし図８に示すように第１の磁石２０６の回転子鉄心円筒部外形側に第１の実施例に比べて厚い回転子鉄心がある。そのため第１の実施例ほどインダクタンスLdは小さくならないが従来例の図１５に対してインダクタンスLdを十分小さくする事が可能である。また第１の磁石２０６は図８のAに示すように回転中心側の磁石角部がインダクタンスLq磁束通路の確保のため面取りによりカットされている。

【００４６】第２の実施例は第１の磁石２０６の断面が略長方形のため作成しやすく、後加工の工数が少なくて磁石作成費が安い磁石を用いて効率向上が可能である。

【００４７】図８のAに示すカットの形状ははR形状等でも良い。次に本発明の第３の実施例の磁石埋込形モータについて説明する。

【００４８】第３の実施例では、１極分の回転子鉄心が回転子の回転方向の逆側に切り欠きを備え磁束方向を変更する事により電流位相進み制御を行った場合のマグネットトルクの減少を抑え高効率のモータを実現するものである。

【００４９】図９は本発明の第３の実施例にあたる磁石埋込形モータの断面図である。図９において、３０２は回転子鉄心、３０４は回転子鉄心の磁石挿入穴、３０６は磁石、１１０は軸穴、３１６は切り欠きである。

【００５０】本実施例では図１に示す第１の実施例の第２の磁石１０８、第２の磁石１０８を挿入するための磁石挿入穴１０４をなくして切り欠き３１６を付加している。固定子１１２、固定子巻線を挿入するスロット１１４の図は省略した。

【００５１】切り欠き３１６は軸方向に回転子鉄心３０２を貫通している。その効果を図１０～図１４を用いて説明する。

【００５２】図１０に電流進みがない場合の各々１相分の電流、磁石磁束による誘起電圧波形とトルクを示す。図１０～図１２の縦軸は適当な数値を与え大きさの目安を示す。トルクは見やすくするため、トルク＝２×電流×誘起電圧で求めた値を表示している。電流位相進みがないため電流と誘起電圧の符号が同じであり１相分のトルクが負を示す所がない。図１０の１相分のTmを発生している場合は、図２３において電流位相進みが０度に対応しTmは最大である。ここで、モータの発生するトルクは例えば固定子に３相の電流を流す場合には１２０度ずつ位相のずれた３つのトルクを加算すれば得られる。

【００５３】図１１は従来例における１相分の位相進み電流、磁石磁束による誘起電圧波形とトルクを示す。図１１では３０度電流位相を進めている。電流位相を進めると図１１に示すように、誘起電圧波形と電流との位相がずれて電流位相が進んだ分だけ負のトルクが発生する事になりマグネットトルクの減少の原因となる。図１１のトルクを発生している場合のTmの減少分を図２３に示す。

【００５４】従来に対し図９のように切り欠き３１６を設ける事で負のトルクを発生させる部分で磁石の磁束を減少させる。図１３に３０度位相進みの正弦波電流を加える場合の電流が同符号である１８０度区間の電流印加位置及び切り欠きによる磁石磁束の方向の変化を示す。また、図１２は第３の実施例における１相分の位相進み電流、磁石磁束による誘起電圧波形とトルクを示す。（誘起電圧波形は厳密にはこのようにはならず歪んだ波形となるがその働きを理解するのには図１２で十分と考える。）図１２と図１３に示すように負のトルクを発生させる磁束を減少させる。またその分の磁束は正のトルクを発生させる所に行き、正のトルクを発生させるのに寄与する磁束を増大させ正のトルクを増大させる。

【００５５】図１４に電流位相とトルクを示す。即ち負のトルクは減少させ、正のトルクは増大し、図２３に示したTmの減少分が少なくなるため、総合トルクが増加する事となる（厳密には，リラクタンストルクは従来に対して小さくなる。）。

【００５６】このように電流位相を進めてもTmがあまり減少せず同一電流に対するトルク発生量が増加する事になり、小型高効率を実現可能となる。

【００５７】また、図１５に各１極の回転方向の逆側の回転子円筒部表面に空隙３１８を設けた場合の６極の磁極、磁石３０６を減少した場合の回転子を示す。図１６に空隙３１８の場合と空隙３１８を鉄心に変えた（空隙がない）場合のシミュレーションによる総合トルク結果を示す。空隙３１８により総合トルクが増加する事が明かであり、同様の効果を得る事は言うまでもない。

【００５８】次に本発明の第３の実施例における他の回転子構造を図１７～１８に示す。図１７に回転子鉄心表

面の４０％程度まで切り欠きを大きくした図を示す。また図１８は磁極の端部ほど切り欠き量を多くしているためエアーギャップ（磁気抵抗）は端部ほど大きくなっており、磁極中心に向けて誘起電圧が大きくなる。ちなみに図９に示す切り欠きの１極分の回転子鉄心表面に対する割合は９％程度である。即ち，通常は３％～１５％程度で良いと考える。しかし４０～６０程度の大きい位相進みでよく駆動する場合は切り欠きが４５％程度までは効果があると考えられる。

【００５９】さらに、図１８は第１の実施例と第３の実施例を供に採用した場合の図である。図１７は各１極の回転方向の逆側の磁石挿入穴３０５の形状を磁石形状に対し大きくした。さらに第１の磁石１０６と第２の磁石１０８の２層の磁石において磁石間のｑ軸の磁束通路を確保するために第１の磁石１０７が磁極中心から回転方向へ移動させている。この事により、第１の実施例と第３の実施例の相乗した効果が得られる。

【００６０】また図１８は１極分に相当する回転子鉄心の両端部に切り欠き３１７を備えた場合である。図１８では磁石による誘起電圧が図１２に示す場合よりさらに中央部（電流位相が９０度付近）が大きくなり，端部（電流位相が０～３０度付近）は切り欠きにより小さくなる。この構造は，駆動電流位相進みが小さく（３０度以内）リラクタンストルクの利用が少ない場合に特に有効である。磁石による誘起電圧の位相と電流位相のズレが小さいため、電流の大きい部分で誘起電圧を大きくする事によって同様に同一電流に対するトルク発生量が増加する事になり、小型高効率を実現可能となる。

【００６１】第３の実施例は回転方向が時計回りか反時計回りに片寄っている場合や、一方の回転方向のみに効率が重視される場合に有効である。

【００６２】ここで正弦波駆動について述べたが矩形波駆動においても同様の効果が得られる事は言うまでもない。また、固定子の相数が変化しても同様の効果を得る。

【００６３】さらに磁石厚が厚いよりも磁束密度の高い磁石を用い磁石厚が薄い方が空隙等が磁石によりさえぎられる事がないため磁石の磁束変更するための切り欠きの効果がよりよく現れる。

【００６４】１極に対し、磁石が１層、２層のみならずさらに多層においても効果が有る事は言うまでもない。

【００６５】

【発明の効果】本発明は回転子の内部に配置した１極分の磁石が回転子円筒部表面の形状に沿った円弧形状の第１の磁石と、第１の磁石とは分離しており異なる形状の第２の磁石とを備える事により、ｉd電流による磁束の発生量を減少させる事となる。そのため総合磁束と総合電流との直交性は改善され、単位電流に対するトルクが増加して高効率化、小型高出力のモータが実現できる。

【図面の簡単な説明】

【図１】本発明の第１の実施例にあたる磁石埋込形モータの断面図

【図２】本発明の第１の実施例において固定子巻線に電流を流した場合の磁束線図

【図３】従来例の２層逆円弧形状において固定子巻線に電流を流した場合の磁束線図

【図４】Ｌdと電流,磁束間の角度との関係を示す図

【図５】本発明の第１の実施例における他の回転子構造を示す図

【図６】本発明の第１の実施例における他の回転子構造を示す図

【図７】本発明の第１の実施例における他の回転子構造を示す図

【図８】本発明の第２の実施例にあたる磁石埋込形モータの断面図

【図９】本発明の第３の実施例にあたる磁石埋込形モータの断面図

【図１０】１相分の電流、磁石磁束による誘起電圧波形とトルクを示す図

【図１１】１相分の電流、磁石磁束による誘起電圧波形とトルクを示す図

【図１２】１相分の電流、磁石磁束による誘起電圧波形とトルクを示す図

【図１３】本発明の第３の実施例の回転子と正弦波電流の印加位置と磁石磁束を示す図

【図１４】本発明の第３の実施例における電流位相進み量とTm、Tr、Tm＋Trとの関係を示す図

【図１５】本発明の第３の実施例における他の回転子構造とそのシミュレーション結果を示す図

【図１６】本発明の第３の実施例における他の回転子構造とそのシミュレーション結果を示す図

【図１７】本発明の第３の実施例における他の回転子構造を示す図

【図１８】本発明の第３の実施例における他の回転子構造を示す図

【図１９】本発明の第３の実施例における他の回転子構造を示す図

【図２０】従来例における磁石埋込形モータの断面図

【図２１】従来例における電流位相進み量とTm、Tr、Tm＋Trとの関係を示す図

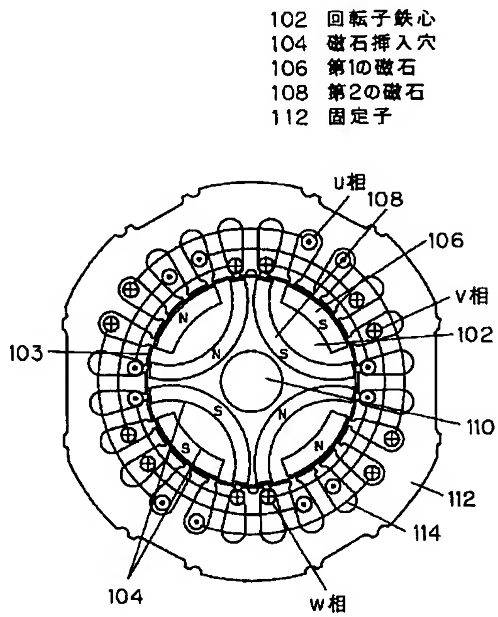
【図２２】総合電流と総合磁束との関係を示す図

【図２３】従来例における最大トルク電流位相とTmの減少分との関係を示す図

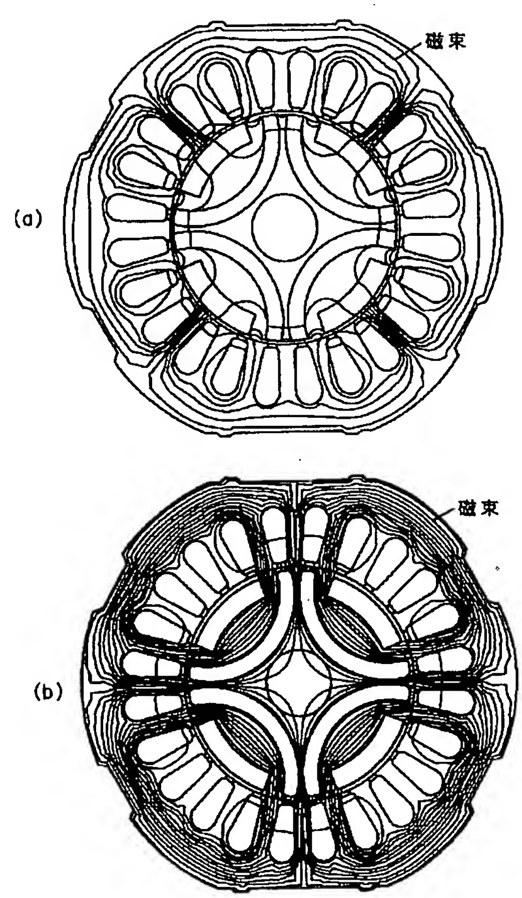
【符号の説明】

１０６　第１の磁石
１０８　第２の磁石
１０４　磁石挿入穴
３１６　切り欠き
３１８　空隙

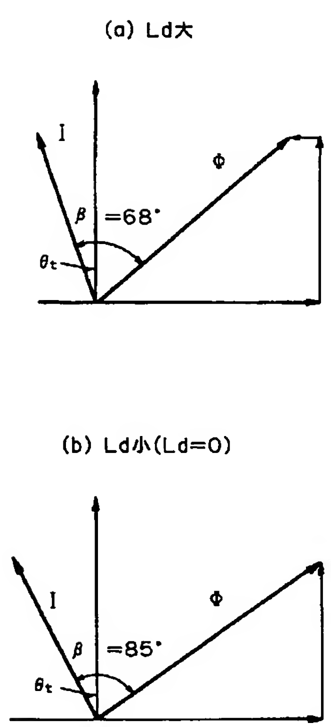
【図1】


102 回転子鉄心
104 磁石挿入穴
106 第1の磁石
108 第2の磁石
112 固定子
U相
108
106
V相
102
103
110
112
114
104
W相
N
S

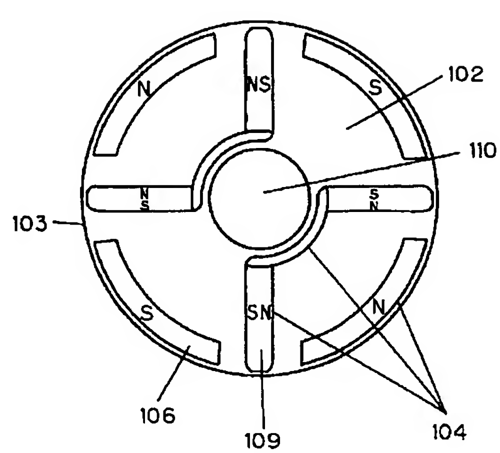
【図2】


磁束
(a)
磁束
(b)

【図4】

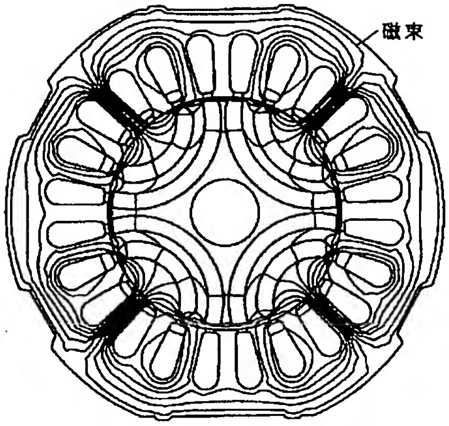

(a) Ld大
I
Φ
β =68°
θt
(b) Ld小(Ld=0)
I
Φ
β =85°
θt

【図5】

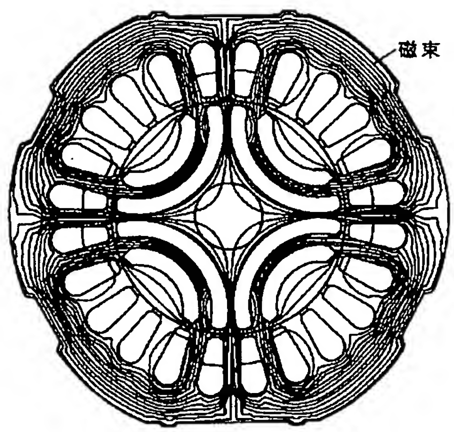

N
NS
S
102
110
103
S
SN
N
106
109
104

【図３】

(a)



(b)



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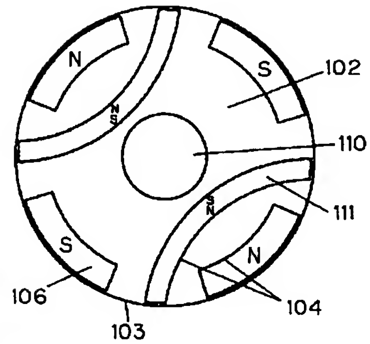

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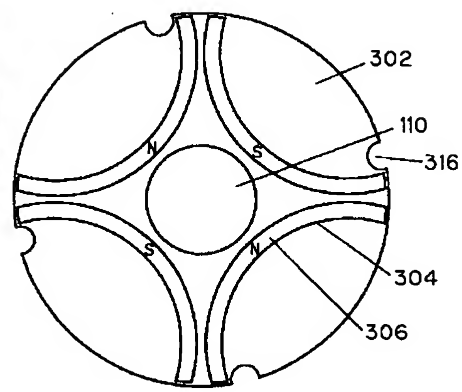

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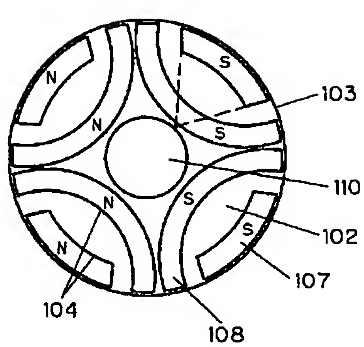
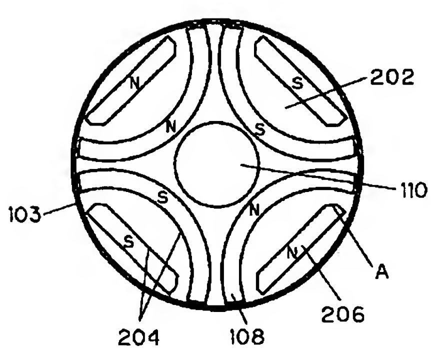
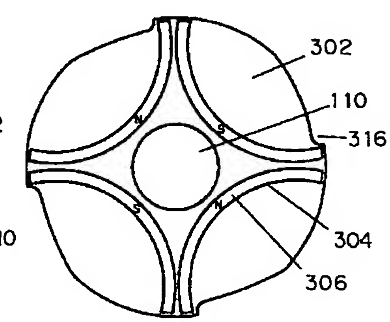


【図８】



【図１７】



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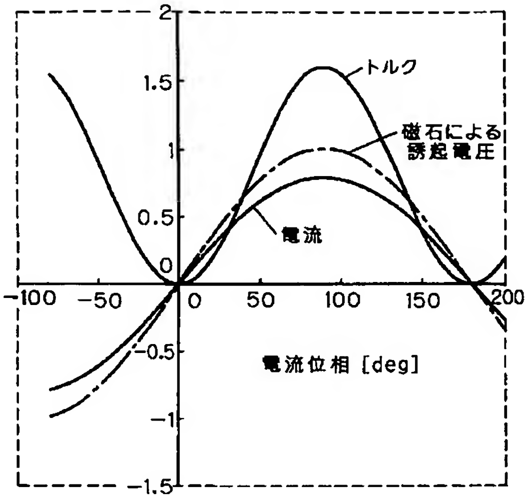
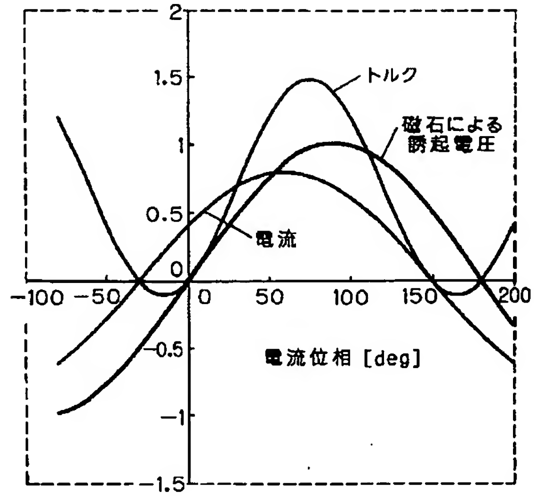
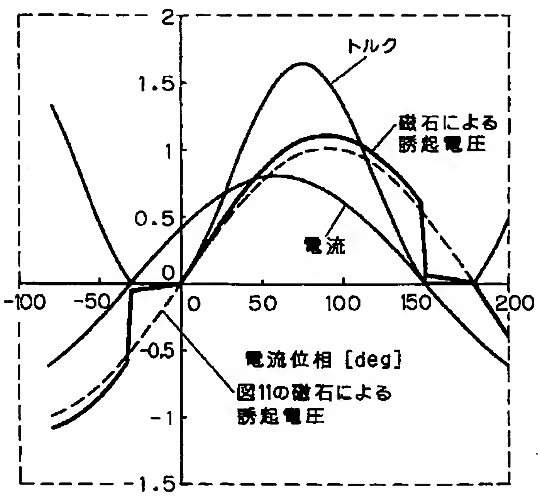


【図11】



【図12】



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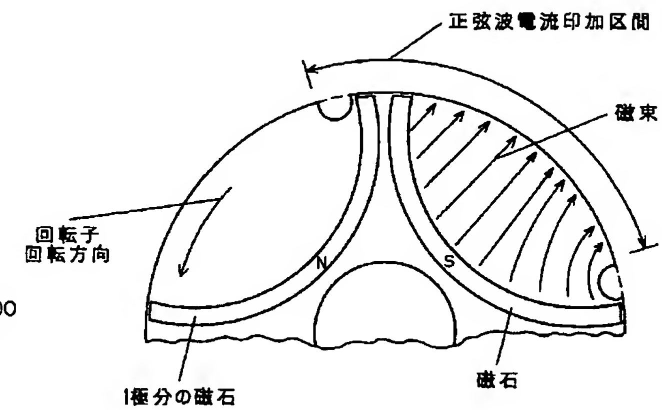

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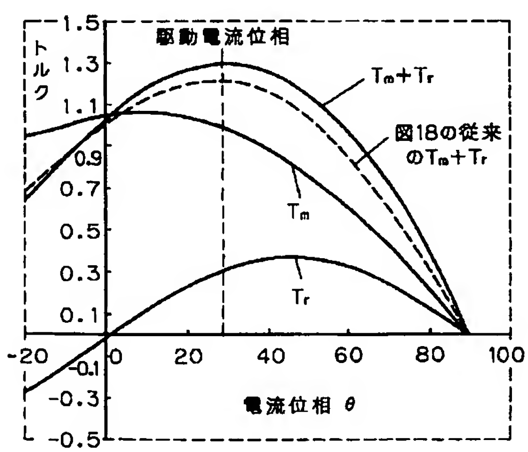

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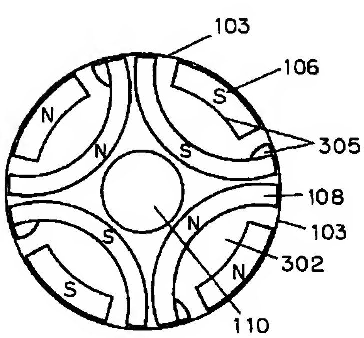

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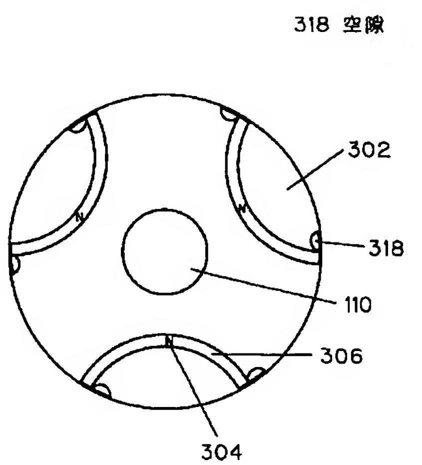
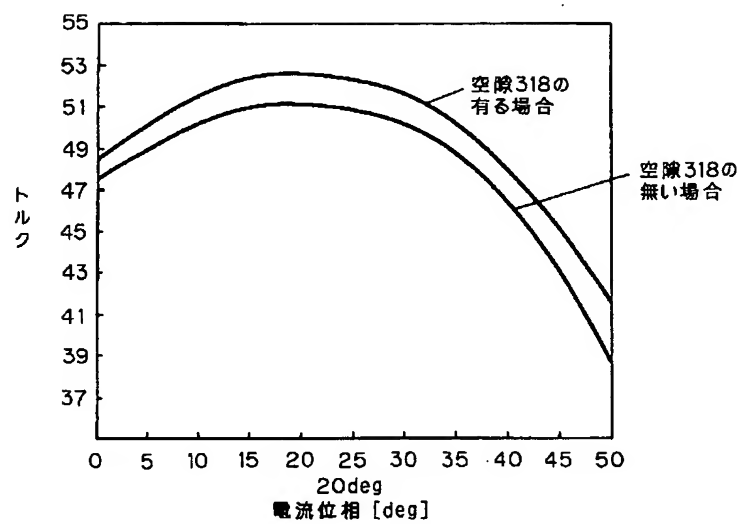
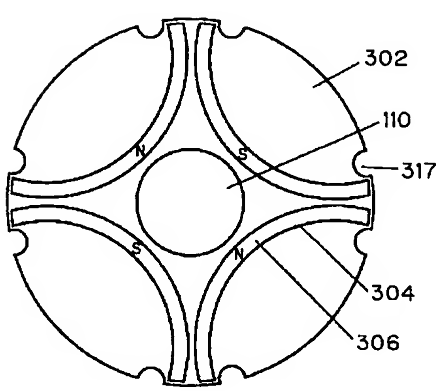


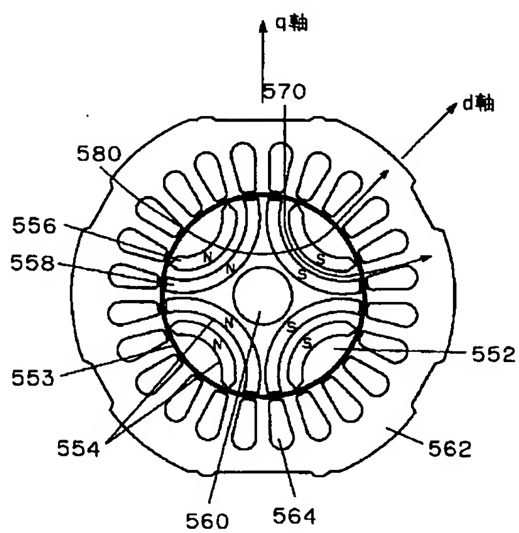
【図１６】



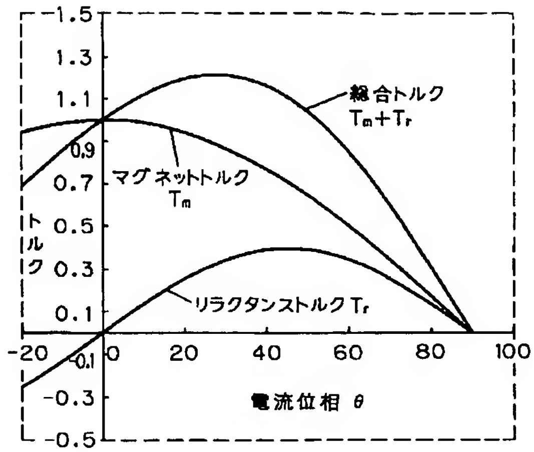
【図１９】



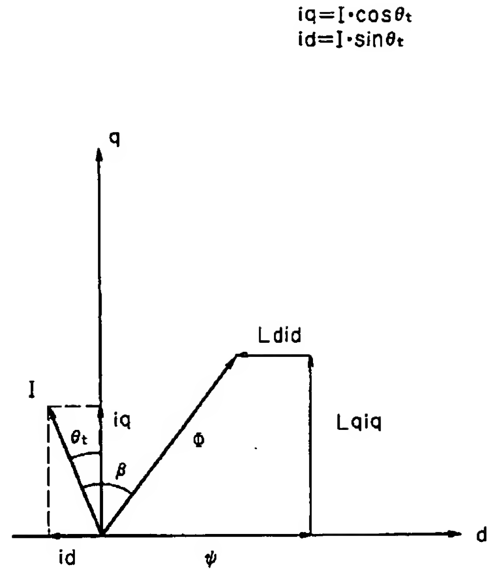
【図２０】



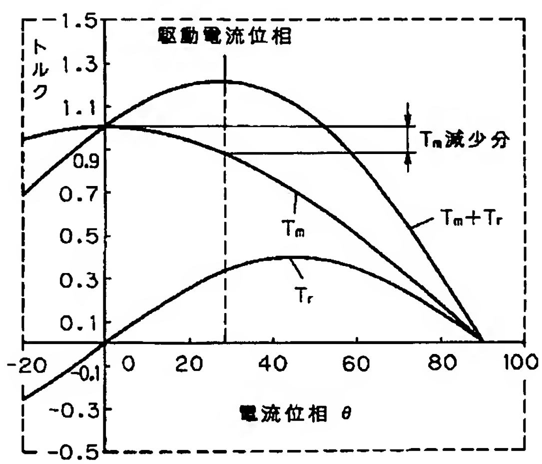
【図２１】



【図２２】



【図２３】



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